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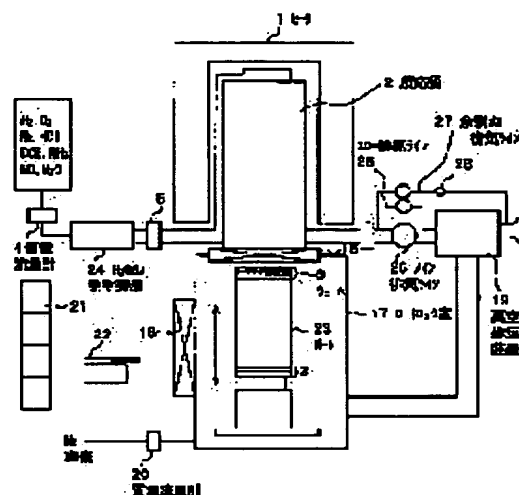
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(54) FORMATION APPARATUS FOR SILICON THERMAL OXIDATION FILM

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a device for forming a silicon thermal oxidation film, wherein evenness of film-thickness is improved while reproducibility is also improved.

SOLUTION: For a formation device for forming a silicon oxide film by allowing oxygen, H₂O gas oxidation species, and a wafer 3 to react directly in a reaction chamber 2, an H₂O gas generating device 24 for obtaining H₂O gas through the catalytic reaction of Pt and Ni from hydrogen gas and oxygen gas is provided at a pre-stage of the reaction chamber 2. Furthermore, a pre-reaction chamber where the transportation atmosphere of the wafer 3 is controlled is provided, while a slow exhaust line 25, a main evacuation line 26, and an excessive gas evacuating line 27 are provided for allowing the reaction chamber 2 to be at a desired vacuum level.



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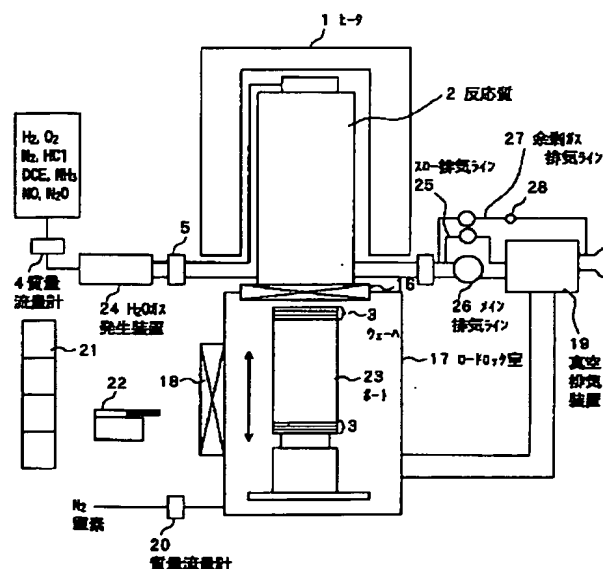
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(54)【発明の名称】 シリコン熱酸化膜の形成装置

(57)【要約】

【課題】 膜厚均一性を向上させるとともに再現性を向上させることができるシリコン熱酸化膜形成装置を得る。

【解決手段】 反応室2において、酸素、 H_2O ガスの酸化種とウェーハ3を直接反応させてシリコン酸化膜を形成する形成装置において、反応室2の前段に、水素ガスと酸素ガスからPt、Niとの触媒反応により H_2O ガスを得るための H_2O ガス発生装置24を有し、さらにウェーハ3の搬送雰囲気制御可能な反応予備室を有し、かつ反応室2を所望の真空度とすることが可能な減圧機構(25、26、27)を有する。



【特許請求の範囲】

【請求項 1】 反応室において、酸素、 H_2O ガスの酸化種とウェーハを直接反応させてシリコン酸化膜を形成する形成装置において、

前記反応室の前段に、水素ガスと酸素ガスから Pt, Ni との触媒反応により H_2O ガスを得るための H_2O ガス発生装置を有することを特徴とするシリコン熱酸化膜の形成装置。

【請求項 2】 請求項 1 記載のシリコン熱酸化膜の形成装置において、

前記ウェーハの搬送雰囲気制御可能な反応予備室を有し、かつ前記反応室を所望の真空度とすることが可能な減圧機構を有することを特徴とするシリコン熱酸化膜の形成装置。

【請求項 3】 請求項 2 記載のシリコン熱酸化膜の形成装置において、前記 H_2O ガス発生装置により得られた H_2O ガスを希釈する希釈用酸素ラインを有することを特徴とするシリコン熱酸化膜の形成装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】この発明は、シリコン熱酸化膜形成装置に関し、特に 100 Å 以下の極薄シリコン熱酸化膜の形成において、膜厚の均一性及び再現性を向上させるためのシリコン熱酸化膜形成装置に関するものである。

【0002】

【従来の技術】図 3 は従来の大気圧雰囲気におけるシリコン酸化膜生成装置の構成図である。このシリコン酸化膜生成装置では、ヒータ 1 で覆われた反応室 2 の内部にウェーハ 3 を装填し、ガス導入口 5 より質量流量計 4 を介して、酸素、水素、 H_2O ガス、窒素、HCl、ジクロロエチレン (Transl, 2-Dichloroethylene; t-DCE)、 N_2O 、NO、 NH_3 ガスをそれぞれ単体、もしくは 2 種類以上の混合ガスとして導入し、反応室 2 を酸化雰囲気とすることによりシリコン熱酸化膜を形成する。

【0003】反応後のガスは、ガス排気口 6 より排気配管 7 を通して排気される。大気圧雰囲気における酸化では、排気側からの制御されないガスの逆拡散が懸念されるため、排気側を陰圧とする必要がある。排気系は、排気ガス中に微量のプロセスガスを含むため、排気ダクトに接続され、数 mm H_2O ～数十 mm H_2O で引かれている。排気配管 7 には自動圧力調整機 8 が設置されており、反応室 2 内部が一定圧力となるよう制御されている。質量流量計 4 とガス導入口 5 の間には、外部燃焼装置である燃焼式の H_2O ガス発生装置 9 が設けられている。

【0004】図 4 に燃焼式の H_2O ガス発生装置の構成図を示す。この H_2O ガス発生装置は、燃焼管 10 の内部を酸素導入管 11 より導入した酸素で置換し、水素導

入管 12 の先端に設置した集光シリコンチップ 13 をハロゲンランプ 14 により 550 °C 以上に加熱した後、水素導入管 12 に水素を導入して炎 15 を生じ燃焼させ、 H_2O ガスを発生する。

【0005】

【発明が解決しようとする課題】ところで、従来より、半導体の高集積化に伴い各種堆積膜厚は縮小しており、ゲート酸化膜厚は量産ベースで 100 Å 以下、研究開発においては 50 Å 以下の適用が検討されている。薄膜化に伴いリーク電流増加が加速的に大きくなるため、これまで問題とならなかった膜厚差に基づくリーク電流の特性に大きな違いを生じることとなる。このため、極薄シリコン酸化膜の膜厚均一性及び再現性を向上させることが必須となり、例えば、50 Å 以下の膜厚均一性の許容範囲としては、膜厚の最大値と最小値の差分で 1 Å 程度が要求されている。

【0006】このような、極薄シリコン酸化膜の膜厚均一性及び再現性の向上が要求される現今においては、酸化速度を落とし、制御性を確保する必要があるが、このため、酸化温度を下げるようにする傾向があるが、この場合は、粘性率低下に伴う応力増加が危惧されるため、必要以上の酸化温度低下は膜質劣化につながる。一般に薄膜では、 H_2O ガスによるいわゆるウェット酸化の方が良好な特性を示すが、ドライ酸化に比較して酸化速度が大きいと、酸素、窒素ガス等により、 H_2O ガスの分圧を下げ、制御性を確保することが有効である。しかし、従来のシリコン熱酸化膜形成装置における燃焼式の H_2O ガス発生装置では、 H_2O ガス発生量は 1 リットル毎分程度が下限となっている。薄膜領域においてもウェット酸化の制御性を確保するためには、1 リットル毎分以下の H_2O ガスを制御性良く供給することができる H_2O ガス発生装置が必要である。

【0007】さらに、上述したように、シリコン熱酸化膜の形成を大気圧雰囲気で行う場合は、圧力調整のために自動圧力調整機 8 を設けるようにしているが、しかし自動圧力調整機 8 はゲージ圧で校正されているため、低気圧、高気圧の到来に伴う気圧変動により反応室内の圧力が相対的に変化し、その結果、膜厚変動を招いている。

【0008】また、酸化膜形成を大気圧雰囲気で行う場合においては、一度に複数枚の処理が可能なバッチ式のシリコン酸化膜生成装置の場合、反応ガスの導入側と排気側で添加ガスの分解成分濃度に差が生じたり、排気側で酸化種に溜りが生じる等の理由により、バッチ内で酸化速度に違いが生じ、バッチ内膜厚均一性を劣化させる。

【0009】なお、これらを解決する手段としては、導入ガスの流速を上げることにより、導入側と排気側の濃度差を小さくすることが有効であるが、大気圧雰囲気中でガス流速を上げるためには、導入ガスの総流量を上げ

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る必要があり、局所的な温度変化を生じ、ウェーハ内膜厚均一性を逆に劣化させてしまう。また、反応室中へウェーハを搬送する際に、大気中の酸素及び水分と反応することにより、制御されない自然酸化膜を形成する。搬送時の反応室の温度により異なるが、形成される自然酸化膜は十数Å程度であり、膜厚が薄くなるに従い、その占める割合が大きくなるため、酸化膜の特性劣化を招く。

【0010】さらに、大気圧雰囲気中で熱酸化膜を形成する場合における、100Å以下の極薄酸化膜形成においては、膜中に印加される電界強度が数MV/cmまで増大し、Bモードと呼ばれる耐圧不良が発生する領域で使用する事となる。Bモード不良の低減には、酸化雰囲気中にHCl及びDCE等の導入が有効であることが示されている。100Å以下の熱酸化膜の諸特性は、シリコン基板との界面に大きく影響されるため、HCl及びDCEの導入は必須であると言える。しかし、HCl及びDCEの導入は、酸化速度が増大することにより制御性が劣化し、膜厚均一性を劣化させている。また、HCl及びDCEは腐食性が高く、反応室2より外部に漏れ出すとSUS部材を腐食する危険性がある。従って上述したような大気圧雰囲気におけるシリコン酸化膜生成装置は、気密性が弱くリークの危険性が高い。また、大気圧におけるリーク量のモニタが困難等の問題、さらにPYRO酸化による水たまりが発生するという問題がある。

【0011】この発明は、かかる従来の問題点を解決するためになされたもので、膜厚均一性を向上させるとともに再現性を向上させることができるシリコン熱酸化膜形成装置を得ることを目的としている。

【0012】

【課題を解決するための手段】上述した課題を解決するため、この発明は、反応室において酸素、H₂Oガスの酸化種とウェーハを直接反応させてシリコン酸化膜を形成する形成装置において、前記反応室の前段に、水素ガスと酸素ガスからPt、Niとの触媒反応によりH₂Oガスを得るためのH₂Oガス発生装置を有してなるものである。

【0013】このような構成によれば、触媒作用を利用するため、水素、酸素流量の低下に伴う炎の消失の問題を解決することができ、1リットル毎分以下の極少量のH₂Oガスを減圧下においても、制御性良く発生させることができる。

【0014】また、この発明は、上述のシリコン熱酸化膜の形成装置において、前記ウェーハの搬送雰囲気を制御可能な反応予備室を有し、かつ前記反応室を所望の真空度とすることが可能な減圧機構を有してなるものである。ここで、反応予備室は大気雰囲気から隔絶された真空気密構造を持つものであり、例えばロードロック室17（あるいはN₂ パージボックス）で構成される。

【0015】このような構成によれば、反応予備室を設けたことにより、反応室へウェーハを搬送する際の雰囲気制御ができ、水分、酸素濃度を共にppbオーダーまで低減することができる。そして、例えば質量流量計を設けて正確に流量を制御して酸素を導入することにより、初期酸化の制御が可能となり、100Å以下の極薄酸化膜の特性を向上させることができる。また、初期酸化を制御することにより、膜厚均一性、再現性がより向上する。さらに反応予備室により、初期酸化を制御した上で反応室を減圧雰囲気とすることにより、導入ガスの総流量を増大させることなくガス流速を上げることができ、反応室内におけるガス導入側と排気側との酸化種濃度差を縮小することができ、バッチ式の膜厚均一性を向上させることができる。また、減圧とすることにより処理温度を下げることなく、酸化速度を下げるため、粘性率低下に伴う応力緩和が期待でき、シリコン酸化膜の物理的特性を向上させることができる。更に、気密性が向上するため、腐食性ガス、爆発性ガス等の有害ガスの漏洩の危険性が少なくなって安全性を高めることができ、また真空度を監視するようにすれば、反応室からのリークを事前に検知することもできる。加えて、数万Pa程度まで減圧することにより、絶対圧力計を使用することができ、外気に左右されずに安定した成膜を行うことができる。また、PYRO酸化による水たまりをも防止することもできる。

【0016】更に、この発明は、上述のシリコン熱酸化膜の形成装置において、前記H₂Oガス発生装置により得られたH₂Oガスを希釈する希釈用酸素ラインを有してなるものである。

【0017】このような構成によれば、H₂Oガス分圧を容易に下げることができ、触媒作用によるH₂Oガス発生装置の効果をより高めることができる。

【0018】

【発明の実施の形態】以下、この発明の実施の形態を極薄シリコン熱酸化膜の形成装置に例をとり図面を用いて説明する。図1は、実施の形態における極薄シリコン熱酸化膜の形成装置としてのロードロック室を有する減圧酸化装置の概略構成を示す図である。この減圧酸化装置においては、ヒータ1で覆われた反応室2の下方にゲートバルブ16を介して、ロードロック室17が設置され、ロードロック室17のウェーハ搬入搬出口はゲートバルブ18により気密に閉塞されている。ロードロック室17には質量流量計20を介してN₂ ガスが導入され、内部を大気からN₂ ガスに置換するための真空排気装置19が設置されている。

【0019】ウェーハ3を移載棚21からウェーハ移載機22を介してポート23に搬送する際、ゲートバルブ18を開放するため、ロードロック室17内部は一旦大気に戻る。ウェーハ搬送終了後、ゲートバルブ18を閉とし、真空排気装置19により真空排気を行うと同時に

N₂ ガスの導入により雰囲気置換を行う。これによりロードロック室内の酸素、水分濃度は 1 ppm 以下とすることができ、反応室 2 へポート 23 を搬入する際、反対に反応室 2 からポート 23 を搬出する際に形成される、制御されない酸化膜を抑制することが可能となり、極薄酸化膜の膜質、膜厚均一性が大幅に改善する。

【0020】ロードロック室 17 の真空置換を行い、さらにポート 23 に積載したウェーハ 3 を反応室 2 内に搬入した後、反応室 2 内部を真空排気装置 19 により排気を行う。反応室 2 が所望の真空度に到達したところで、質量流量計 4 を介して酸素、水素、H₂ O ガス、窒素、HCl、t-DCE、N₂ O、NO、NH₃ ガスをそれぞれ単体、もしくは 2 種類以上の混合ガスとして導入することにより酸化膜を形成する。H₂ O ガスはガス導入口前段に設けた H₂ O ガス発生装置 24 に酸素、水素ガスを供給し、触媒反応させることにより正確に制御される。反応室 2 を減圧とすることで、導入ガスの平均自由工程が伸び、また未反応の酸化種を速やかに排気することができ、溜りが生じにくいこと等により、特に、ポートスロット間の膜厚均一性が向上する。HCl、t-DCE 等の腐食性ガスを用いた場合、到達真空度により事前にリークチェックを行うことが可能であり、外部への漏洩の危険性を小さくできる。また、外部の気圧変動に左右されず、酸化速度も低下するため、再現性も向上する。

【0021】排気系は、真空排気装置 19 に繋がるスロー排気ライン 25、メイン排気ライン 26 と、反応室 2 が大気圧以上となった場合に余剰ガスが流れる余剰ガス排気ライン 27 で構成されている。スロー排気ライン 25 は、反応室 2 の真空度を大気圧から徐々に下げる場合に用いられ、パーティクルの舞上がりによるウェーハ 3 への付着を防止する。スロー排気ライン 25 より太いメイン排気ライン 26 は、短時間で所望の真空到達度を得ることができる。また、余剰ガス排気ライン 27 には逆止弁 28 が設置されており、排気系からの戻りが無く、反応室 2 内部の酸化種を高純度に保つことが可能となる。

【0022】極薄シリコン熱酸化膜形成には、導入ガスの制御性が重要であり、このための H₂ O ガス発生装置 24 を図 2 に示す。この H₂ O ガス発生装置は、水素ガス、酸素ガス、Pt、Ni 等の触媒反応を用いている。この H₂ O ガス発生装置は、図 3 に示した H₂ O ガス発生装置（外部燃焼装置）9 と置換える形で使用する。ヒータ 29 で加熱した触媒反応炉 30 に酸素ガス、水素ガス、窒素ガスをそれぞれ MFC（マスフローコントローラ）33～35 を介して導入し、触媒作用により H₂ O ガスを発生させる。触媒の材質は、例えば Pt、Ni である。

【0023】従来の H₂ O ガス発生装置 9 では、低水分領域になると消火してしまい、水分が発生しなくなる可

能性があったが、この実施の形態における触媒反応を用いると、水素 2 mol に対して酸素が 1 mol あれば、1 mol の H₂ O ガスが生成され、原理的には質量流量計で制御可能な流量の H₂ O ガスを得ることができ、極薄膜形成における制御性が向上する。

【0024】また、発生した H₂ O ガスが液化しないよう触媒反応炉 30 から反応室 2 までの配管加熱を行う。触媒の構成部材に Pt、Ni を使用しているが、ウェーハ 3 上への汚染は無い。

【0025】さらに、この実施の形態では、触媒反応炉 30 の後段に、未反応の水素ガスを検出する水素検知器 31 を設置することにより、万一、水素検知レベルが設定値を越える場合、信号を取り込み、水素ガスを止め、反応室 2 内をパージさせるシーケンスにジャンプするようにしているため安全である。また、触媒反応炉 30 にて発生した H₂ O ガス濃度を供給酸素により希釈制御するための希釈酸素ライン 32 及び MFC 36 を設置したことにより、H₂ O ガス濃度を広範囲で制御することができ、極薄シリコン熱酸化膜の再現性が向上する。

【0026】

【発明の効果】以上に詳述したように、この発明によれば、触媒作用による H₂ O ガス発生装置を利用するようにしたので、1 リットル毎分以下の極少量の H₂ O ガスを制御性良く発生することができ、シリコン熱酸化膜の再現性を向上させることができると共にその制御性を向上させることができる。

【0027】また、この発明によれば、触媒作用による H₂ O ガス発生に加え、反応予備室を設けるようにしたので、酸化初期時の酸化膜成長を制御することができると共に、反応室を減圧雰囲気としたのでガス導入側と排気側の酸化種濃度差を縮小することができ、バッチ式の膜厚均一性を向上させることができる。さらに処理温度を下げることなく酸化速度を下げることができ、粘性率低下に伴う応力緩和が期待でき、シリコン酸化膜の物理的特性を向上させることができる。また、気密性が向上するため、腐食性ガス、爆発性ガス等の有害ガスの漏洩の危険性が少なく安全となる。さらに、絶対圧力計を使用できる場合は、外気に左右されず安定した成膜が可能となる。

【0028】さらに、この発明によれば、H₂ O ガスの希釈用酸素ラインを設けたことにより、H₂ O ガスの分圧を容易に下げることが可能となり、H₂ O ガス濃度をより広範囲に制御することができ、極薄シリコン熱酸化膜の再現性、制御性をより向上させることができる。

【図面の簡単な説明】

【図 1】発明の実施の形態に係る極薄シリコン熱酸化膜の形成装置の構成を示す概略図である。

【図 2】発明の実施の形態における H₂ O ガス発生装置の構成を示す概略図である。

【図 3】従来の大気圧雰囲気におけるシリコン酸化膜生

成装置の構成を示す概略図である。

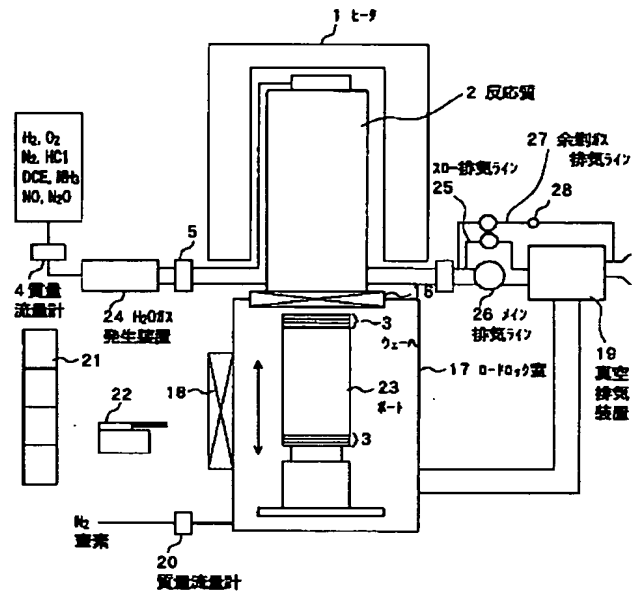
【図4】従来のH₂/Oガス発生装置の構成を示す概略図である。

【符号の説明】

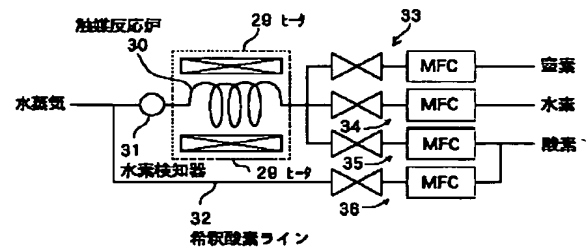
- 1 ヒータ
2 反応室
3 ウェーハ
19 真空排気装置

- * 23 ボート
24 H₂/Oガス発生装置
25 スロー排気ライン
26 メイン排気ライン
27 余剰ガス排気ライン
30 触媒反応炉
31 水素検知器
* 32 希釈酸素ライン

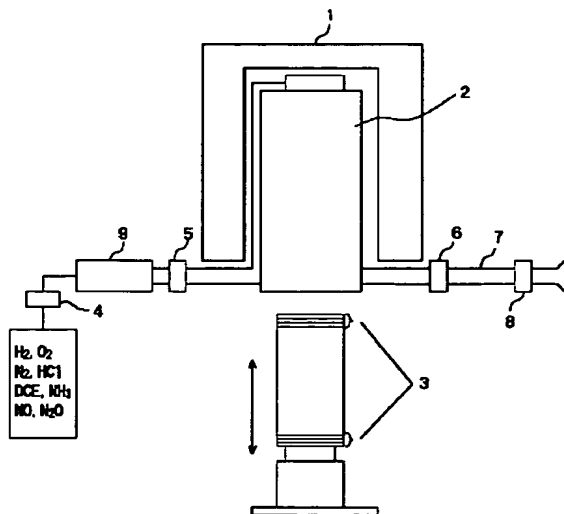
【図1】



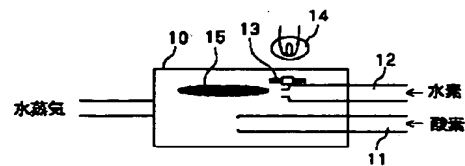
【図2】



【図3】



【図4】



CERTIFICATION OF ENGLISH LANGUAGE TRANSLATION OF JAPANESE

APPLICATION NO. 2003-301982

I hereby declare and state that I am knowledgeable of each of Japanese and English languages.

I hereby certify that the attached English translation is a complete and accurate translation of Japanese Patent Application No. 2003-301982.

Signed this 16th day of September, 2008


Haruhiko MIYAMOTO

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[International Patent Classification] H01L 21/31

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[Amount of Payment] ¥21,000

[List of Thing(s) to be Submitted]

[Name of Thing(s)]	Claims for Patent	1
[Name of Thing(s)]	Specification	1
[Name of Thing(s)]	Drawings	1
[Name of Thing(s)]	Abstract	1

[Document Name] Claims for Patent

[Claim 1]

A producing method of a semiconductor device, characterized by comprising:

a step for transferring a plurality of substrates into a processing chamber;

a step for supplying oxygen-containing gas from upstream of said plurality of substrates transferred into said processing chamber;

a step for supplying hydrogen-containing gas from upstream of said plurality of substrates transferred into said processing chamber and from a half-way location corresponding to a region where said plurality of substrates exist;

a step for allowing said oxygen-containing gas and hydrogen-containing gas to react with each other in said processing chamber to oxidize said plurality of substrates; and

a step for transferring said processed substrates out from said processing chamber, wherein

in the step for supplying said hydrogen-containing gas, flow rates of said hydrogen-containing gas supplied from the supply locations are different from each other.

[Claim 2]

A producing method of a semiconductor device as recited in claim 1, characterized in that

the step for oxidizing said substrates is carried out in a state in which pressure in said processing chamber is lower than atmospheric pressure.

[Claim 3]

A producing method of a semiconductor device as recited in claim 1, characterized in that

said oxygen-containing gas is at least one of gases selected from the group consisting of oxygen gas and nitrous oxide gas, and said hydrogen-containing gas is at least one of gases selected from the group consisting of hydrogen gas, ammonia gas and methane gas.

[Claim 4]

A producing method of a semiconductor device as recited in claim 1, characterized in that

said oxygen-containing gas is oxygen gas and said hydrogen-containing gas is hydrogen gas.

[Claim 5]

A producing method of a semiconductor device as recited in claim 1, characterized in that

a surface of said substrate includes different crystal orientation planes, or includes polycrystalline silicon by CVD or silicon nitride.

[Claim 6]

A substrate processing apparatus, characterized by

comprising:

a processing chamber which processes a plurality of substrates;

a holding tool which holds said plurality of substrates in said processing chamber;

an oxygen-containing gas supply line which supplies oxygen-containing gas to said plurality of substrates from upstream of said plurality of substrates;

hydrogen-containing gas supply lines which supply hydrogen-containing gas to said substrates from upstream of said plurality of substrates and from a half-way location corresponding to a region where said plurality of substrates exists;

an exhaust line which exhaust inside of said processing chamber; and

a control means which controls such that flow rates of said hydrogen-containing gas supplied from the hydrogen-containing gas supply lines are different from each other.

[Claim 7]

A substrate processing apparatus as recited in claim 6, characterized in that

said substrate processing apparatus further comprises a control means which controls such that pressure in said

processing chamber becomes lower than atmospheric pressure.

[Claim 8]

A substrate processing apparatus as recited in claim 6, characterized in that

said hydrogen-containing gas supply lines comprise a supply line which supplies hydrogen-containing gas from upstream of said plurality of substrates and a supply line which supplies said hydrogen-containing gas from a half-way location corresponding to the region where the plurality of substrates exist, said supply lines are disposed independently from each other, and said control means controls such that flow rates of said supply lines are different from each other.

[Claim 9]

A substrate processing apparatus as recited in claim 6, characterized in that

said hydrogen-containing gas supply lines comprise a supply line which supplies hydrogen-containing gas from upstream of said plurality of substrates and a plurality of supply lines which supply said hydrogen-containing gas from a plurality of half-way locations corresponding to the region where the plurality of substrates exist, said supply lines are disposed independently from each other, and said control means controls such that flow rates of said supply lines are different from each other.

[Claim 10]

A substrate processing apparatus as recited in claim 8,
characterized in that

said supply lines respectively have mass flow controllers.

[Claim 11]

A substrate processing apparatus as recited in claim 9,
characterized in that

said supply lines respectively have mass flow controllers.

[Document Name] Specification

[Title of the Invention] Producing Method of
Semiconductor Device and Substrate Processing Apparatus

[Technical Field]

[0001]

The present invention relates to a producing method of a semiconductor device and a substrate processing apparatus for subjecting a surface of a substrate such as a semiconductor wafer to oxidation processing.

[Background Art]

[0002]

In a step for allowing oxidation reaction to take place directly on an Si substrate (wafer) which is formed in the course of semiconductor process, and from which different Si crystal planes are exposed, in a conventional oxidation technique, oxidation speed is different depending upon crystal plane. As a result, there is a problem that an oxide film having uneven film thickness is formed on a substrate, and characteristics are varied depending upon location on the substrate.

[0003]

As a step in which different Si crystal planes are exposed from a substrate, there is element-isolation known as Shallow Trench Isolation (STI), and a forming step of a vertical type

MOS transistor in which an Si substrate is embedded. By forming a groove on the Si substrate by dry etching, different surface orientations are exposed from a side surface and a bottom surface of the groove. In the STI step, Si_3N_4 is exposed from the substrate surface by the oxidation step, and it is required to bring oxidation speed on the Si_3N_4 closer to oxidation speed on the Si substrate, and to obtain the same oxide film thicknesses as close as possible.

[0004]

As conventional oxidation methods, there are a dry oxidation method and a wet oxidation method. In the dry oxidation method, the pressure of atmosphere in a reaction chamber is set to normal pressure or vacuum pressure, and oxidation processing of a substrate is carried out in atmosphere in which oxygen partial pressure is adjusted by means of oxygen alone, or N_2 , Ar and the like. In the wet oxidation method, oxidation processing of a substrate is carried out utilizing moisture formed by mixing oxygen and hydrogen with each other in a front stage of a reaction chamber. As a method for forming moisture by mixing hydrogen and oxygen with each other, there are widely utilized a method in which temperature is increased to ignition temperature of hydrogen and oxygen or higher by resistance heating or lamp light-gathering heating to burn, and a method in which hydrogen and oxygen are allowed to react

with each other by catalysis at ignition temperature or lower
(see patent document 1).

[patent document 1] Japanese Patent Application
Laid-open No. H11-204511

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0005]

According to the conventional oxidation method,
oxidation speed of (110) plane having greater Si atom surface
density becomes two times greater than that of (100) plane
in a thin film oxidation region depending upon Si atom surface
density of a surface of an Si substrate between surface
orientations of different Si substrates, e.g., between the
(100) plane and the (110) plane. Further, oxidation
resistance is high on an Si_3N_4 , the Si_3N_4 is used as a barrier
layer against oxidation, and oxidation does not proceed almost
at all.

[0006]

Contrary to this, in a method in which oxygen and hydrogen
are respectively introduced into a reaction chamber having
vacuum atmosphere from independent gas supply systems and
oxygen and hydrogen are made to be directly react in the vicinity
of a substrate to be processed, because reaction with the
substrate proceeds before forming water, growing speed at

initial stage of oxidation is fast, a difference in growing speeds between surface orientations of different Si substrates and a growing speed on the Si_3N_4 is reduced and as a result, a difference in film thickness can remarkably be reduced, and isotropic oxidation can be carried out.

[0007]

When isotropic oxidation is to be carried out by a batch type vertical apparatus, however, there is a problem in the conventional method that because gas is supplied from only upstream of the substrates which are subjects to be processed, hydrogen concentration is varied in the processing chamber due to disposition locations of the substrates multi-stacked in the vertical direction, and as a result, thicknesses of the formed oxide films are largely varied.

[0008]

It is an object of the present invention to provide a producing method of a semiconductor device and a substrate processing apparatus which are capable of producing a high quality semiconductor device while suppressing a case in which hydrogen concentration is varied depending upon the disposition locations of the substrates and oxide film thicknesses are largely varied when isotropic oxidation is carried out in a batch-type vertical apparatus.

[Means to Solve the Problem]

[0009]

A first feature of the present invention is a producing method of a semiconductor device, characterized by comprising:

a step for transferring a plurality of substrates into a processing chamber;

a step for supplying oxygen-containing gas from upstream of said plurality of substrates transferred into said processing chamber;

a step for supplying hydrogen-containing gas from upstream of said plurality of substrates transferred into said processing chamber and from a half-way location corresponding to a region where said plurality of substrates exist;

a step for allowing said oxygen-containing gas and hydrogen-containing gas to react with each other in said processing chamber to oxidize said plurality of substrates; and

a step for transferring said processed substrates out from said processing chamber, wherein

in the step for supplying said hydrogen-containing gas, flow rates of said hydrogen-containing gas supplied from the supply locations are different from each other.

[0010]

A second feature of the present invention is a producing method of a semiconductor device in the first feature, characterized in that

the step for oxidizing said substrates is carried out in a state in which pressure in said processing chamber is lower than atmospheric pressure.

[0011]

A third feature of the present invention is a producing method of a semiconductor device in the first feature, characterized in that

said oxygen-containing gas is at least one of gases selected from the group consisting of oxygen gas and nitrous oxide gas, and said hydrogen-containing gas is at least one of gases selected from the group consisting of hydrogen gas, ammonia gas and methane gas.

[0012]

A fourth feature of the present invention is a producing method of a semiconductor device in the first feature, characterized in that

said oxygen-containing gas is oxygen gas and said hydrogen-containing gas is hydrogen gas.

[0013]

A fifth feature of the present invention is a producing method of a semiconductor device in the first feature, characterized in that

a surface of said substrate includes different crystal orientation planes, or includes polycrystalline silicon by CVD

or silicon nitride.

[0014]

A sixth feature of the present invention is a substrate processing apparatus, characterized by comprising:

a processing chamber which processes a plurality of substrates;

a holding tool which holds said plurality of substrates in said processing chamber;

an oxygen-containing gas supply line which supplies oxygen-containing gas to said plurality of substrates from upstream of said plurality of substrates;

hydrogen-containing gas supply lines which supply hydrogen-containing gas to said substrates from upstream of said plurality of substrates and from a half-way location corresponding to a region where said plurality of substrates exists;

an exhaust line which exhaust inside of said processing chamber; and

a control means which controls such that flow rates of said hydrogen-containing gas supplied from the hydrogen-containing gas supply lines are different from each other.

[0015]

A seventh feature of the present invention is a substrate

processing apparatus in the sixth feature, characterized in that

said substrate processing apparatus further comprises a control means which controls such that pressure in said processing chamber becomes lower than atmospheric pressure.

[0016]

A eighth feature of the present invention is a substrate processing apparatus in the sixth feature, characterized in that

said hydrogen-containing gas supply lines comprise a supply line which supplies hydrogen-containing gas from upstream of said plurality of substrates and a supply line which supplies said hydrogen-containing gas from a half-way location corresponding to the region where the plurality of substrates exist, said supply lines are disposed independently from each other, and said control means controls such that flow rates of said supply lines are different from each other.

[0017]

A ninth feature of the present invention is a substrate processing apparatus in the sixth feature, characterized in that

said hydrogen-containing gas supply lines comprise a supply line which supplies hydrogen-containing gas from upstream of said plurality of substrates and a plurality of supply lines

which supply said hydrogen-containing gas from a plurality of half-way locations corresponding to the region where the plurality of substrates exist, said supply lines are disposed independently from each other, and said control means controls such that flow rates of said supply lines are different from each other.

[0018]

A tenth feature of the present invention is a substrate processing apparatus in the eighth feature, characterized in that

said supply lines respectively have mass flow controllers.

[0019]

A eleventh feature of the present invention is a substrate processing apparatus in the ninth feature, characterized in that

said supply lines respectively have mass flow controllers.

[Effect of the Invention]

[0020]

According to the present invention, it is possible to largely reduce a difference in growing speed of oxide film on silicon surfaces of different surface orientations on silicon substrates formed during the process step of various semiconductor wafers as compared with the conventional oxidation method. When a plurality of substrates are to be

processed by a batch type vertical apparatus, it is possible to suppress variation in oxide film thickness caused by variation of hydrogen concentration on each substrate, and it is possible to produce a high quality semiconductor device.

[Best Mode for Carrying out the Invention]

[0021]

The present inventors found that, isotropic oxidation, oxygen and hydrogen directly react with a substrate heated by the heating source in the vicinity of the substrate and its film forming speed is supply rate-determining reaction of hydrogen, and the inventors devised that two or more hydrogen supply passages are brought into communication with the reaction chamber so as to constantly set forming speed of films on substrates stacked on one another in the vertical direction. With this, it is possible to eliminate attenuation of hydrogen concentration in downstream direction of gas flow in the reaction chamber that is caused when hydrogen supplied from upstream of the reaction chamber reacts with oxygen supplied from upstream of the reaction chamber directly above the substrate and is consumed. The present inventors succeeded in enhancing the consistency of thicknesses of oxide films on a plurality of substrates when isotropic oxidation is carried out using a batch type vertical apparatus.

[0022]

Embodiments of the present invention will be explained based upon the drawings.

Fig. 1 is to explain a batch type vertical semiconductor producing apparatus (oxidation apparatus) as a substrate processing apparatus of this embodiment. A reaction furnace 20 includes a reaction tube 21. A boat 2 as a substrate holding tool is inserted into a reaction chamber (processing chamber) 4 formed by the reaction tube 21. The holding tool 2 holds a plurality of semiconductor wafers (silicon wafers) 1 as substrates in a multi-stacked manner in their horizontal attitudes at gaps (substrate pitch distances) from one another. A lower portion of the reaction tube 21 is opened so that the holding tool 2 is inserted thereinto, and this opening is tightly closed with a seal cap 22. A resistance heater 5 as a heat source is disposed around the reaction tube 21. Connected to the reaction tube 21 are oxygen supply line 7 which supplies oxygen (O_2) gas as oxygen-containing gas to substrates from upstream thereof, a first hydrogen supply line 8 which supplies hydrogen (H_2) gas as hydrogen-containing gas to the substrates from the upstream thereof, and a second hydrogen supply line 9 which supplies hydrogen (H_2) gas as hydrogen-containing gas to the substrates from an intermediate location corresponding to a region where the plurality of substrates exist. It is preferable to provide a plurality

of second hydrogen supply lines 9. The supply lines 7, 8 and 9 are respectively provided with solenoid valves 6 for supplying gas and stopping the supply of gas. An exhaust line 23 is connected to the reaction tube 21 for exhausting process gas, and a vacuum pump 3 is connected to the exhaust line 23. During the processing of the substrates, the pressure in the reaction tube 21 is brought into a predetermined pressure (vacuum) lower than the atmospheric pressure by the vacuum pump 3, and control means 24 controls the pressure.

[0023]

Next, a method for subjecting the substrates to the oxidation processing as one step of a producing step of the semiconductor device using the above-described oxidation apparatus will be explained.

[0024]

If one batch of wafers 1 is transferred to the holding tool 2, the holding tool 2 in which the plurality of wafers 1 are loaded is loaded into a processing chamber 4 of the reaction furnace 20 whose heated state is maintained by the heat source 5, and the reaction tube 21 is tightly closed with the seal cap 22. The reaction tube 21 is evacuated from the vacuum pump 3, and the control means 24 controls such that the pressure in the furnace becomes equal to predetermined processing pressure which is lower than the atmospheric pressure. The

temperature in the furnace is increased, and the control means 24 controls the temperature in the furnace becomes equal to the predetermined processing temperature. Thereafter, the oxygen supply line 7 supplies oxygen into the processing chamber 4, the first hydrogen supply line 8 and the second hydrogen supply line 9 supply hydrogen gas into the processing chamber 4. With this, oxygen gas and hydrogen gas directly react with each other in the vicinity of the substrate heated by the heat source 5, reaction species are generated, and the wafers 1 are subjected to the oxidation processing. This oxidation processing is called radical oxidation processing or reduced pressure oxidation processing, etc. Examples of the processing temperature are 500 to 1000°C, and examples of the processing pressure are 1 to 133 Pa.

[0025]

If the oxidation processing of wafers 1 is completed, residual gas is eliminated by purge using evacuation or inert gas, the temperature in the furnace is reduced to a predetermined temperature and then, the holding tool 2 is unloaded from the reaction furnace 20, and the holding tool 2 is brought into a standby state until all of the wafers 1 supported by the holding tool 2 are cooled. When the wafers 1 held by the holding tool 2 which is in the standby state are cooled to a predetermined temperature, the wafers are

collected by a substrate transfer device or the like.

[0026]

According to this embodiment, a difference in growing speeds of oxide films on silicon surfaces of different surface orientations on wafer substrates formed through a process step of various semiconductor wafers can largely be reduced as compared with the conventional oxidation method (dependence on surface orientation of processed wafer can be reduced). In addition, when a plurality of wafers are to be processed by a vertical substrate processing apparatus, it is possible to suppress the variation in oxide film thicknesses which might be caused due to variation in hydrogen concentration on each wafer. The present invention is especially effective when surfaces of a substrates which are subjected to oxidation processing have different crystal orientation surfaces, or are polycrystalline silicon by CVD or a silicon nitride.

[0027]

Although a case in which oxygen gas is used as the oxygen-containing gas, and a case in which hydrogen gas is used as the hydrogen-containing gas are explained in the above embodiment, at least one of gasses selected from a group comprising oxygen (O_2) gas and nitrous oxide (N_2O) gas can be used as the oxygen-containing gas, and at least one of gasses selected from a group comprising hydrogen (H_2) gas, ammonia

(NH₃) and gas and methane (CH₄) gas can be used as the hydrogen-containing gas.

[Embodiment 1]

[0028]

Next, a substrate processing apparatus of the embodiment 1 will be described in detail using Fig. 4.

The pressure in the reaction chamber 4 is reduced through the vacuum pump 3. The oxygen supply line 7 and the first hydrogen supply line 8 which are independent from each other are connected to the reaction chamber 4. Oxygen gas and hydrogen gas are not mixed with each other before they are supplied to the reaction chamber 4, and active hydrogen and oxygen react with each other in the very vicinity of the wafer, which is an object to be processed, heated by the heat source 5. Therefore, oxidation speed can be increased in the initial stage of oxidation.

[0029]

The acceleration of the oxidation speed depends on hydrogen concentration in the vicinity of the wafers. In a structure in which hydrogen gas is supplied only through the hydrogen supply line 8 from upstream of an arrangement of the wafers 1, hydrogen gas contributes to the oxidation reaction and with this, the hydrogen gas is consumed toward the downstream of the arrangement of the wafers, the hydrogen gas

concentration is different depending upon the disposition location of the wafer and as a result, film thickness consistency is largely deteriorated.

[0030]

To compensate a deficiency of hydrogen gas which is consumed by the oxidation reaction and depleted downstream, a second, a third... hydrogen supply lines 9 are provided as supply lines of hydrogen, in addition to the first hydrogen supply line 8. With this, it is possible to supply hydrogen gas to substrates from a plurality of locations on the way to a region where the plurality of wafers 1 exist. Therefore, it is possible to improve the film thickness consistency of the plurality of wafers 1 disposed in the reaction chamber 4. The second and third hydrogen supply lines 9 are independent from each other, gas jet openings thereof are directed toward the wafers (opposed to the wafers 1), and hydrogen can be supplied to locations in the vicinity of the wafers without being mixed with oxygen supplied from the oxygen supply line 7 connected to an upstream portion of the arrangement of the wafers.

[Embodiment 2]

[0031]

Next, a substrate processing apparatus of the embodiment 2 will be described in detail using Fig. 2.

Like the embodiment 1, the first hydrogen supply line 8 which is independent from the oxygen supply line 7 is connected to the reaction chamber 4. The embodiment 2 is different from the embodiment 1 in that the second, the third...hydrogen supply lines 9 which are independent from the first hydrogen supply line 8 are connected to a plurality of (multi-system) nozzles which rise along an inner wall of the reaction tube 21 in the reaction chamber 4 and which have different lengths. More specifically, the second, the third... hydrogen supply lines 9 are connected to a second hydrogen supply nozzle 10, a third hydrogen supply nozzle 11..., which have different lengths in the direction of the arrangement of the wafers, and hydrogen concentration in the reaction chamber in the direction of the arrangement of the wafers (vertical direction) can be adjusted. Tip ends of the nozzles are respectively opened, and the openings are gas jet openings. The gas jet openings are directed upward in the reaction chamber 4, not toward the wafers 1, but the gas jet openings may be directed toward the wafers (opposed to the wafers 1) like the embodiment 1.

[Embodiment 3]

[0032]

Next, a substrate processing apparatus of the embodiment 3 will be described in detail using Fig. 3.

Like the embodiment 1, the first hydrogen supply line 8 which is independent from the oxygen supply line 7 is connected to the reaction chamber 4, and to compensate a deficiency of hydrogen gas which is consumed by the oxidation reaction and depleted downstream, a plurality of second, third...hydrogen supply lines 9 are provided, in addition to the first hydrogen supply line 8. The embodiment 3 is different from the embodiment 1 in that each of the oxygen supply line 7, the first hydrogen supply line 8 and the second, the third...hydrogen supply lines 9 has a mass flow controller 12 capable of adjusting a flow rate. With this, it is possible to adjust oxygen flow rate and hydrogen flow rate flowing through the respective supply lines, and to finely control the hydrogen concentration in the reaction chamber.

[Embodiment 4]

[0033]

Next, a substrate processing apparatus of the embodiment 4 will be described in detail using Fig. 4.

Like the embodiment 1, the first hydrogen supply line 8 which is independent from the oxygen supply line 7 is connected to the reaction chamber 4. The embodiment 4 is different from the embodiment 1 in that a porous nozzle 13 is provided instead of the second, the third...hydrogen supply lines 9 which are independent from the first hydrogen supply line 8 and which

are half-way supply nozzles for adjusting hydrogen concentration in the reaction chamber. A tip end of the porous nozzle 13 is sealed, and the porous nozzle 13 is provided at its side surface with at least two small holes. It is possible to control the hydrogen concentration in the reaction chamber without using a plurality of hydrogen lines. The porous nozzle 13 may be provided at its side surface with at least two kinds small holes having different diameters, i.e., opening areas. That is, the small holes may have at least two or more different diameters. With this, it is possible to finely control the flow rate of hydrogen flowing out from the respective small holes.

[Embodiment 5]

[0034]

Next, a substrate processing apparatus of the embodiment 5 will be described in detail using Fig. 5.

Fig. 5 shows an embodiment in which a flowing direction of gas in the reaction chamber 4 is different from that of each of the embodiment 1 to 4 shown in Figs. 1 to 4. In the embodiments 1 to 4, gas basically flows in the reaction chamber 4 from above to below. In the embodiment 5, gas in the reaction chamber 4 flows from below to above. In the structure of the reaction chamber 4, an outer tube (reaction tube) 21 includes an inner tube 14 therein, and

an interior of the reaction chamber 4 is divided by the inner tube 14. Oxygen and hydrogen which are reaction gases are supplied into the inner tube 14 from a lower portion of the reaction chamber respectively. A half-way supply hydrogen supply nozzle rises vertically inside of the inner tube 14. Gas after reaction and unreacted gas pass outside of the inner tube 14 (through a space between the inner tube 14 and the outer tube 21) and the gases are exhausted from the exhaust line 23 and the vacuum pump 3.

[Embodiment 6]

[0035]

Next, a substrate processing apparatus of the embodiment 6 will be described in detail using Figs. 6 and 7.

According to the embodiment 6, many H_2 gas lines (multi-system) are prepared as hydrogen-containing gas supply lines, flow rates of H_2 in the gas lines are set different from each other and are optimized so as to enhance film thickness consistency between the wafers. This substrate processing apparatus is called a vertical furnace, and comprises the reaction furnace which carries out vacuum oxidation (radical oxidation) processing for substrates, and a transfer chamber for transferring wafers existing below the reaction furnace. When the oxidation processing is to be carried out, the boat carrying a plurality of wafers is brought into the reaction

furnace from the transfer chamber. Fig. 6 shows a state in which wafers are loaded on the boat in the transfer chamber. Fig. 7 shows a state in which boat on which the wafers are loaded is loaded into the reaction furnace. The structure of the reaction furnace 20 is the same as that of the embodiment 5, and gas flows in the reaction chamber 4 from below to above. In Fig, 6, the heater is not shown for the sake of convenience.

[0036]

The structure of the reaction chamber 4 is also the same as that of the embodiment 5. The outer tube (reaction tube) 21 includes the inner tube 14 therein, and an interior of the reaction chamber 4 is divided by the inner tube 14. When the vacuum oxidation processing is to be carried out for the substrates, O_2 as oxygen-containing gas and H_2 as hydrogen-containing gas which are reaction gas are supplied inside of the pressure-reduced inner tube 14 from upstream of the arrangement of wafers through the oxygen supply line (nozzle) 7 and the first hydrogen supply line (nozzle) 8 which are provided in the furnace opening flange of a lower portion of the reaction chamber 4. The second hydrogen-containing gas supply line (nozzle) 10 and the third hydrogen-containing gas supply line (nozzle) 11 which are half-way supply lines (nozzles) for adjusting hydrogen concentration vertically rise inside of the inner tube 14.

These second hydrogen-containing gas supply nozzle 10 and third hydrogen-containing gas supply nozzle 11 are formed and disposed in the same manner as the embodiment 2. Hydrogen gas is supplied to the substrates 1 from a plurality of half-way portions of a region where the plurality of wafers 1 exist through the second hydrogen-containing gas supply nozzle 10 and the third hydrogen-containing gas supply nozzle 11. In this manner, O_2 is introduced from one line (nozzle), but H_2 is introduced from many (multi-system) lines (nozzles). Each of the H_2 lines has an MFC (mass flow controller) for adjusting the flow rate (not shown). The O_2 line may also have an MFC (mass flow controller). These MFCs provided in the lines are controlled by the control means 24. Gas after reaction and unreacted gas pass outside of the inner tube 14 (through a space between the inner tube 14 and the outer tube 21) and the gases are exhausted from the exhaust line and the vacuum pump (both not shown).

[0037]

The present inventors carried out the vacuum oxidation (radical oxidation) processing for the substrates using this substrate processing apparatus as an experiment, and found that the film thickness consistency between the wafers was largely varied by changing the film thickness of H_2 of each H_2 line. A result of the experiment is shown in Fig. 8. Fig.

8 shows a result of wafer film thicknesses at various positions on the boat obtained while changing the flow rate of H_2 from each H_2 nozzle. The lateral axis shows positions of the boat (slot numbers as measured from the lowermost slot). The vertical axis shows film thickness. In the drawing, (short/intermediate/long) means H_2 nozzles 8, 11 and 10, and H_2 (short/intermediate/long) = 220/145/135cc means that set flow rates of the H_2 nozzle 8, H_2 nozzle 11 and H_2 nozzle 10 are 220sccm, 145sccm and 135sccm, respectively. There exists one O_2 nozzle 71, and its flow rate is 2500sccm and is constant. It can be found from Fig. 8 that the film thickness consistency is enhanced if the H_2 flow rates of the H_2 nozzles are different from each other as compared with a case in which the flow rates of the lines are constant. The optimal film thickness consistency is obtained when (short/intermediate/long) = 220/145/135cc. From this, it is preferable that flow rates of H_2 supplied from the lines are set greater toward upstream (smaller toward downstream). This result is one obtained when 172 wafers are processed at the same time, the temperature in the furnace is 850°C, the pressure is 35Pa and there are three H_2 lines. Of course, the same tendency is shown even if the number of wafers to be processed is increased or decreased, or the number of H_2 lines is two, four or more. This result is obtained when a double reaction tube type furnace body having

CVD structure is used, but even with a structure having no inner tube such as a diffusion furnace is used, it can be said that the same effect can be obtained. It can be found from this result, the film thickness consistency between the wafers can be enhanced by optimizing the flow rate of H_2 in each line.

Since the reaction generated in the furnace is supply rate-determining, gas becomes depleted toward the exhausting direction and consistency between wafers becomes poor, but since the flow rate of H_2 to be half-way supplied may be set such that only deficiency of gas can be compensated, the most upstream has the greatest flow rate accordingly.

[Embodiment 7]

[0038]

Next, the embodiment 7 will be explained in detail using Fig. 9.

The embodiment 7 relates to a result of an experiment carried out using the substrate processing apparatus of the embodiment 6.

Fig. 9 shows distribution of wafer film thicknesses on various positions on the boat generated by changing the processing (film forming) pressure. There exists one O_2 nozzle, and its flow rate is 2500sccm and is constant. There are three H_2 nozzles, and their flow rates are set to short/intermediate/long = 240/145/135cc. It can be found from

Fig. 9 that the processing pressure is preferably equal to or lower than 35Pa. It can also be found that the higher the pressure is, the poorer the film thickness distribution between wafers becomes. From this, it can be said that the flow rates of the H₂ nozzles and the number of the nozzles should be optimized by the processing pressure.

[Embodiment 8]

[0039]

Next, the embodiment 8 will be explained in detail with using Fig. 10.

The embodiment 8 relates to a result of an experiment carried out using the substrate processing apparatus of the embodiment 6.

Fig. 10 shows distribution of wafer film thicknesses on various positions on the boat generated by changing the processing (film forming) temperature. There exists one O₂ nozzle, and its flow rate is 2500sccm and is constant. There also exists one H₂ nozzle, and its flow rate is 240sccm. It can be found from Fig. 10 that the processing temperature is preferably equal to or lower than 700°C. As the processing temperature is lower, the film thickness distribution is improved, and as the processing temperature is higher, the film thickness distribution becomes poorer. From this, it can be said the flow rates of the H₂ nozzles and the number

of the nozzles should be optimized by the processing temperature like the embodiment 7.

[Brief Description of the Drawings]

[0040]

[Fig. 1]

Fig. 1 is a schematic sectional view showing a substrate processing apparatus according to an embodiment 1 of the present invention.

[Fig. 2]

Fig. 2 is a schematic sectional view showing a substrate processing apparatus according to an embodiment 2 of the present invention.

[Fig. 3]

Fig. 3 is a schematic sectional view showing a substrate processing apparatus according to an embodiment 3 of the present invention.

[Fig. 4]

Fig. 4 is a schematic sectional view showing a substrate processing apparatus according to an embodiment 4 of the present invention.

[Fig. 5]

Fig. 5 is a schematic sectional view showing a substrate processing apparatus according to an embodiment 5 of the present invention.

[Fig. 6]

Fig. 6 is a schematic sectional view showing a substrate processing apparatus according to an embodiment 6 of the present invention.

[Fig. 7]

Fig. 7 is a schematic sectional view showing a substrate processing apparatus according to an embodiment 7 of the present invention.

[Fig. 8]

Fig. 8 is a diagram showing a result of an experiment according to the embodiment 6 of the present invention.

[Fig. 9]

Fig. 9 is a diagram showing a result of an experiment according to the embodiment 7 of the present invention.

[Fig. 10]

Fig. 10 is a diagram showing a result of an experiment according to the embodiment 8 of the present invention.

[Description of the Symbols]

[0041]

1 wafer

2 wafer holding tool

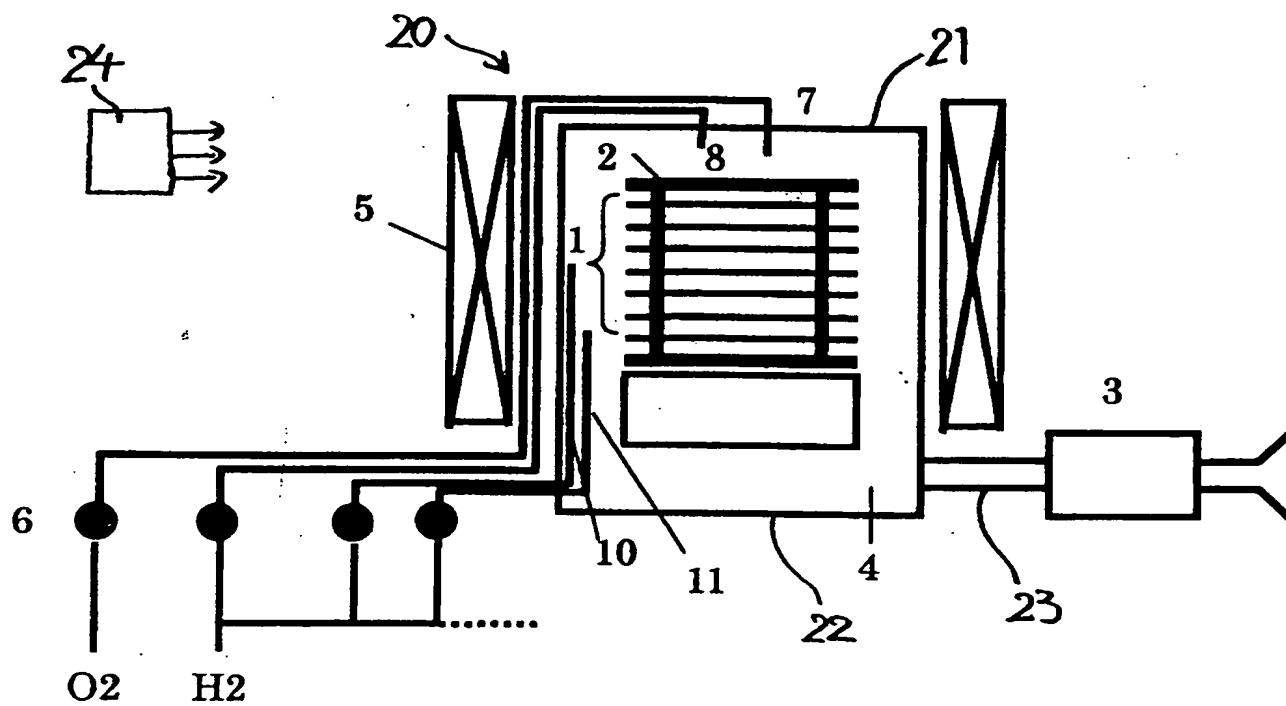
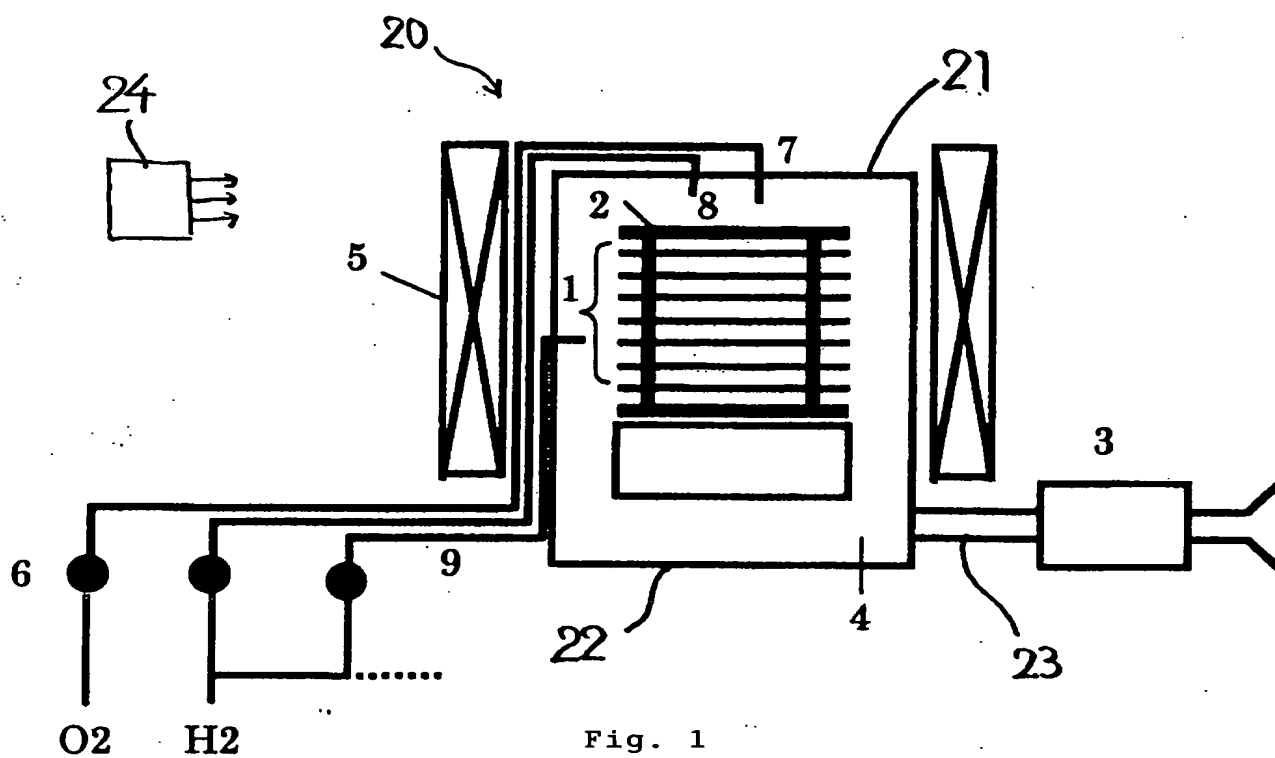
3 vacuum pump

4 reaction chamber

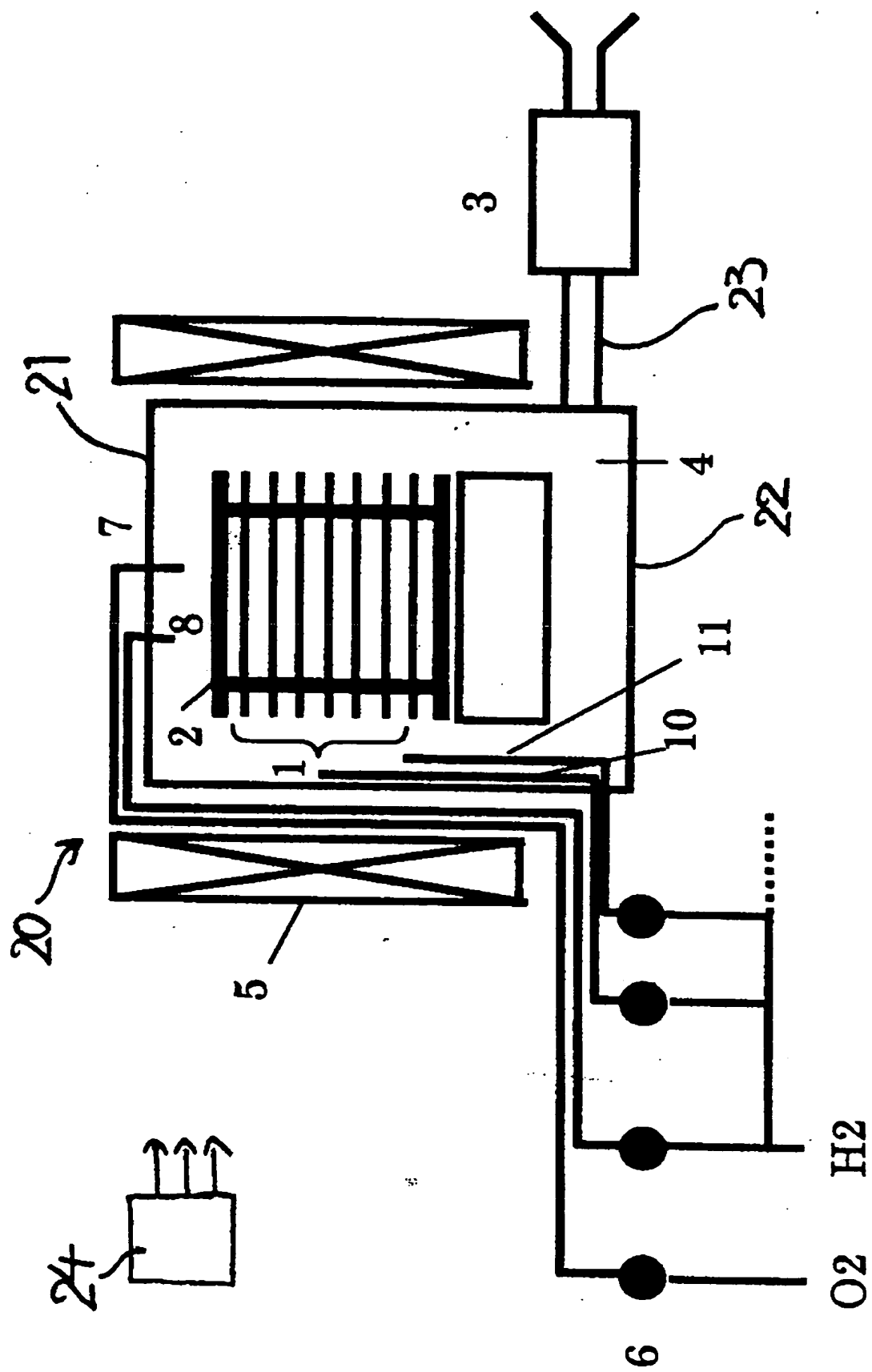
5 heat source

- 6 solenoid valve
- 7 oxygen supply line
- 8 first hydrogen supply line
- 9 second hydrogen supply line
- 10 first hydrogen supply nozzle
- 11 second hydrogen supply nozzle
- 12 mass flow controller
- 13 porous nozzle

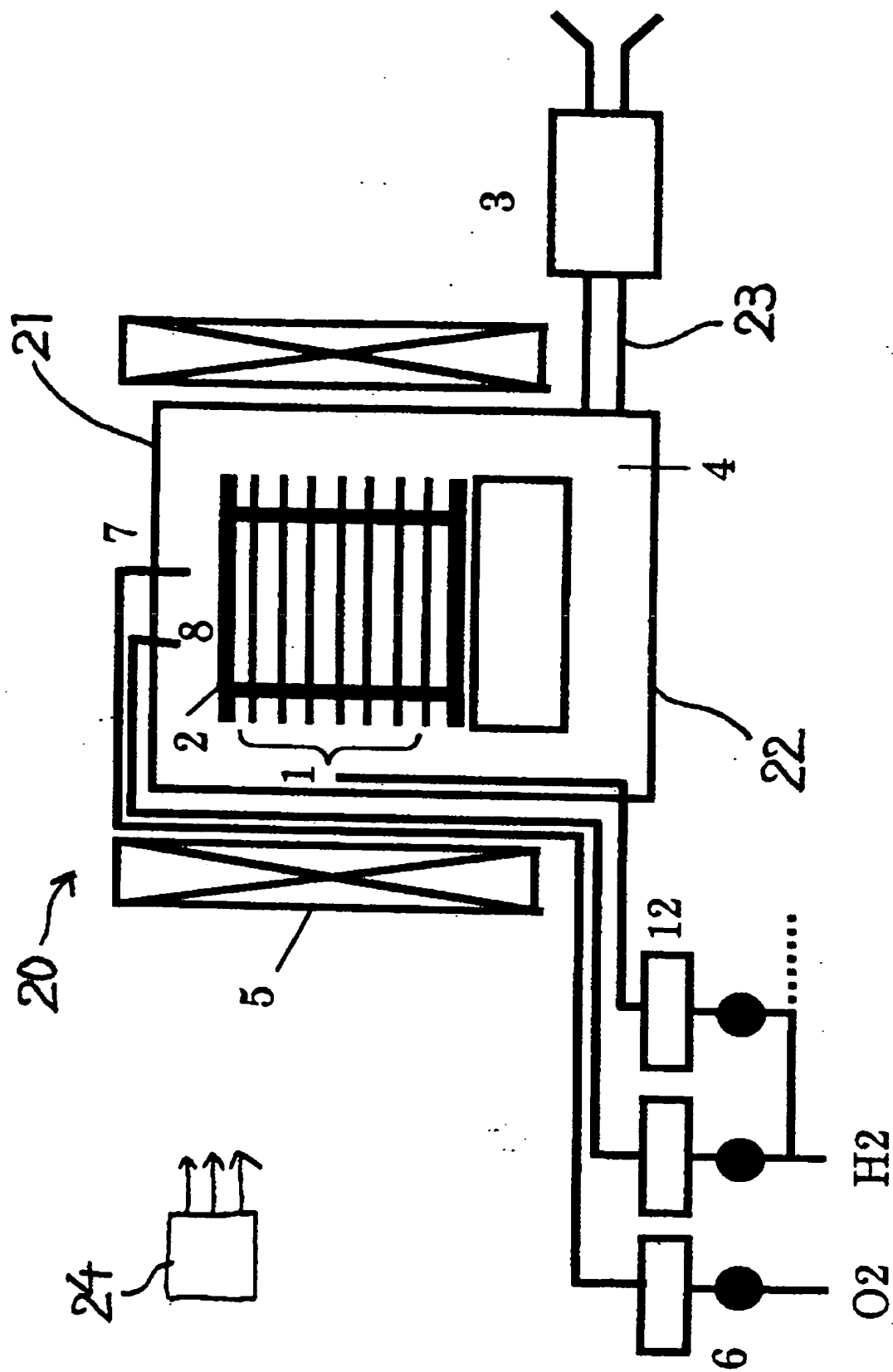
[Fig. 1]



[Fig. 2]



[Fig. 3]



[Fig. 4]

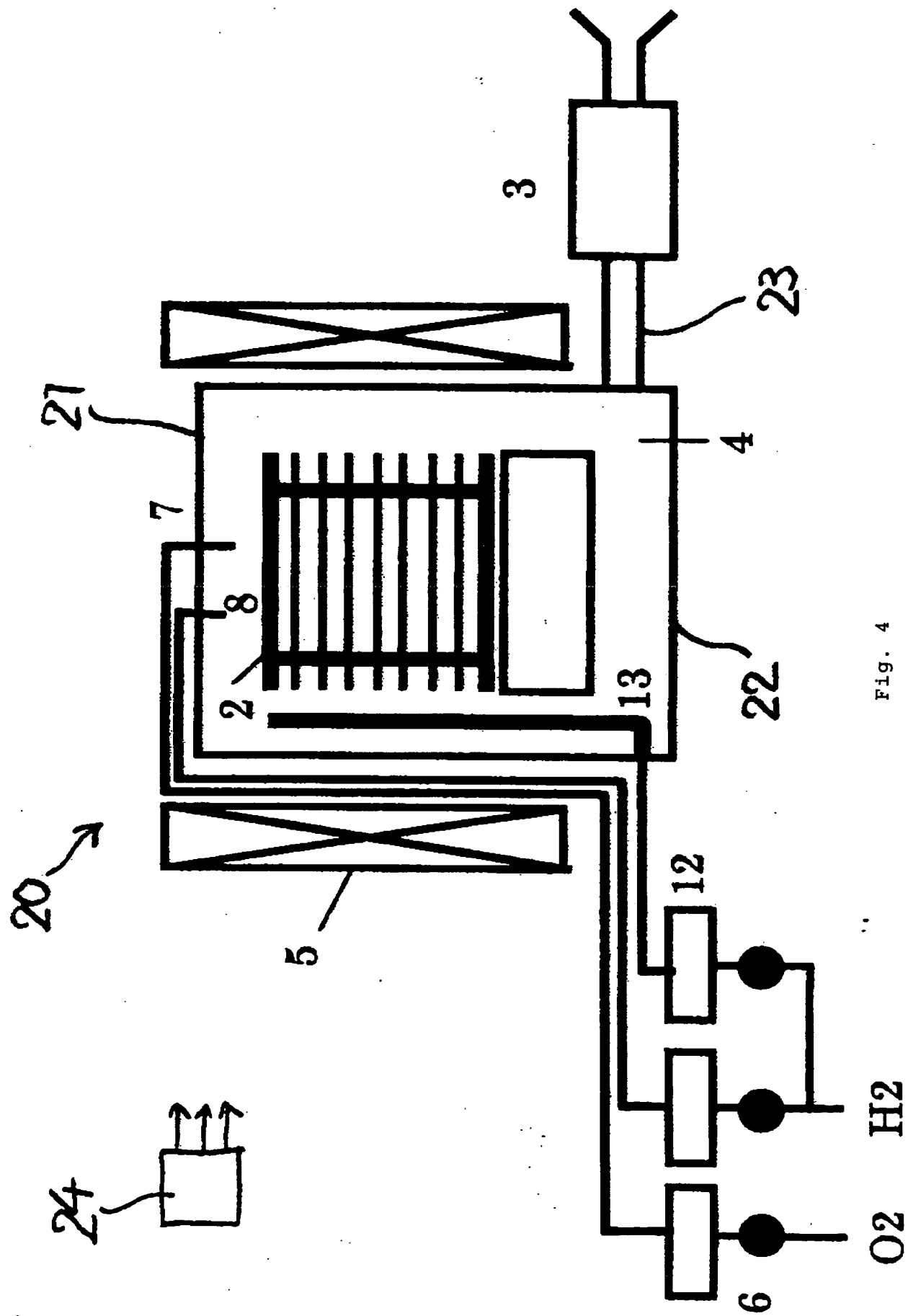
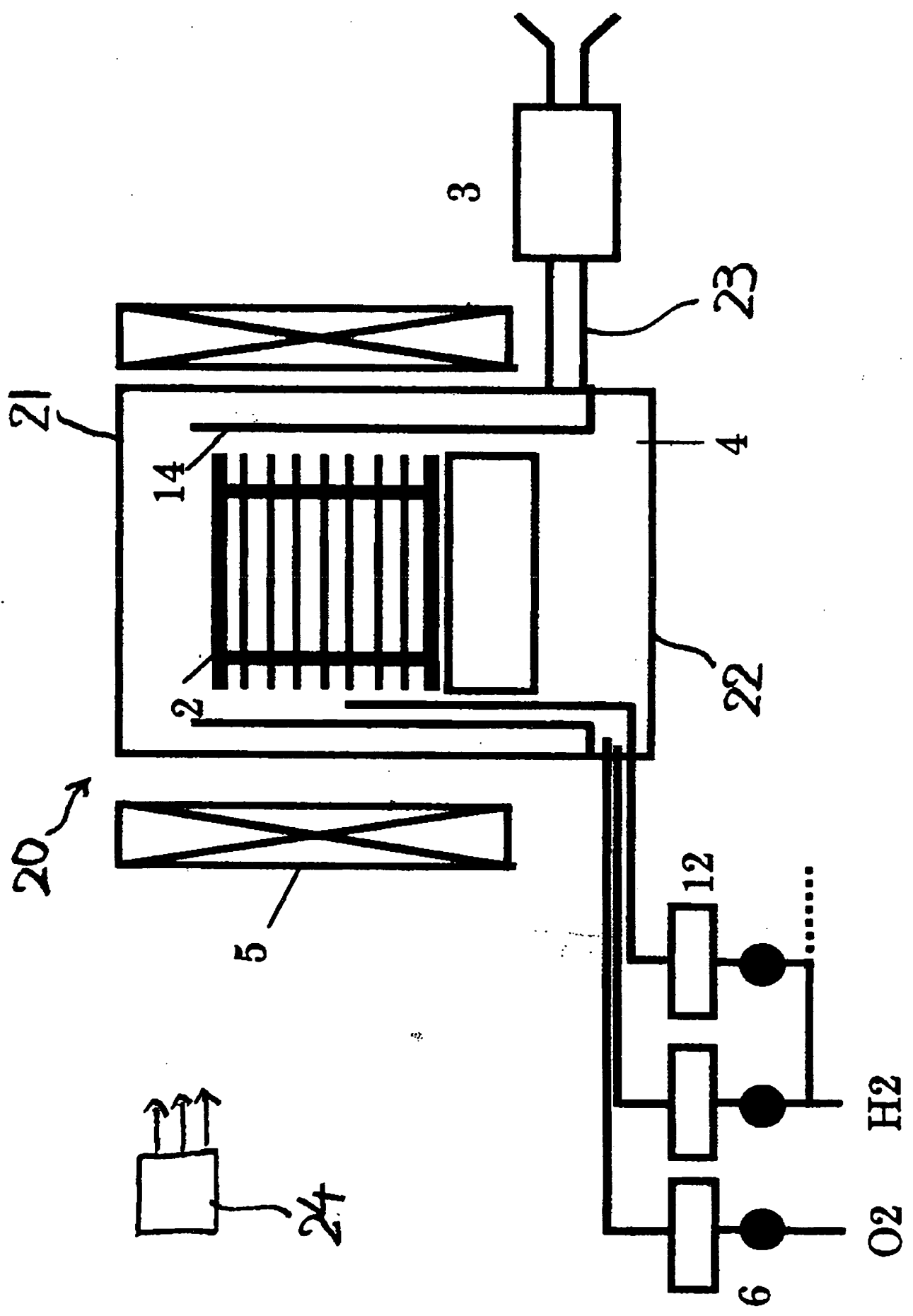
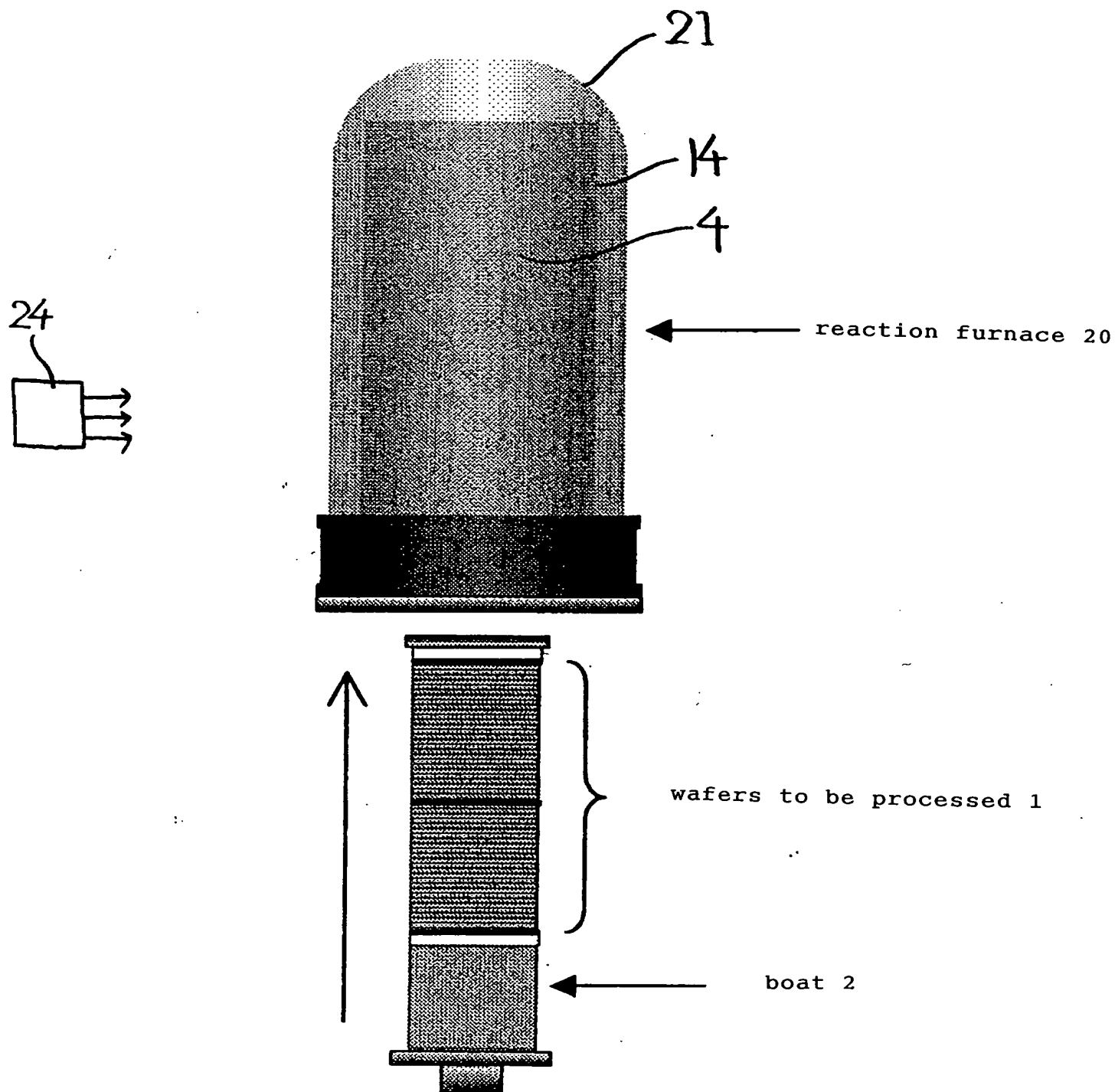


Fig. 4

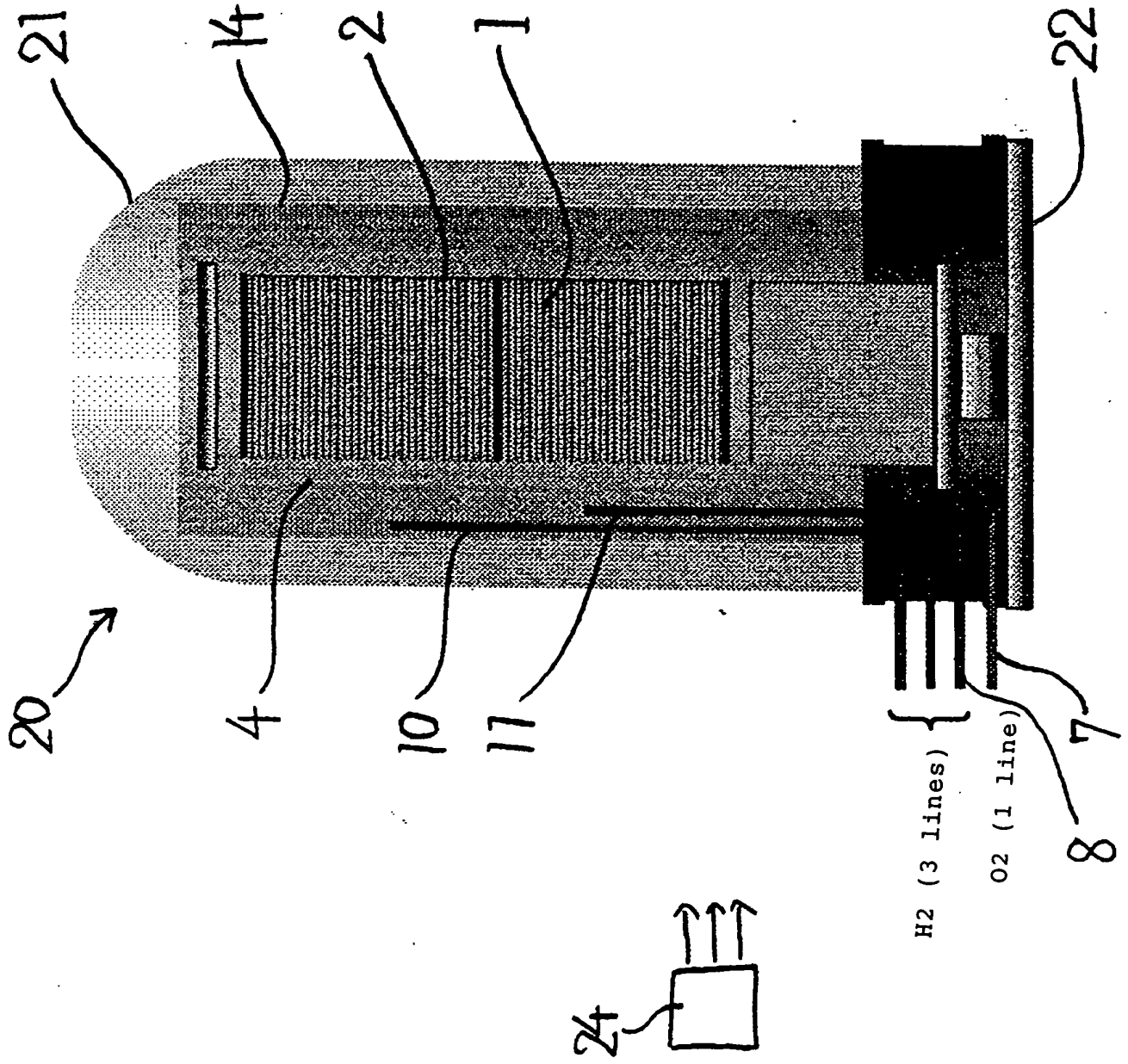
[Fig 5]



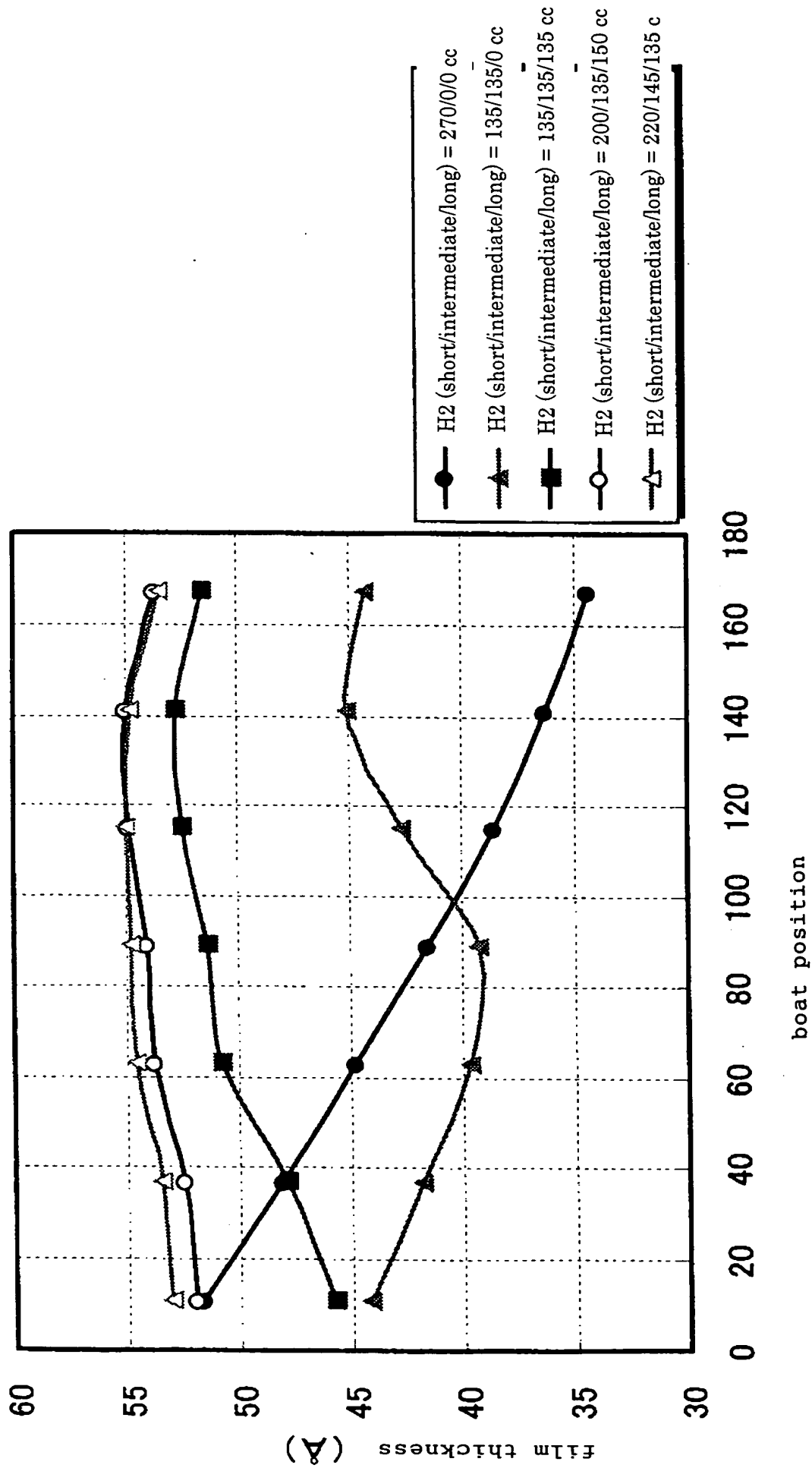
[Fig. 6]



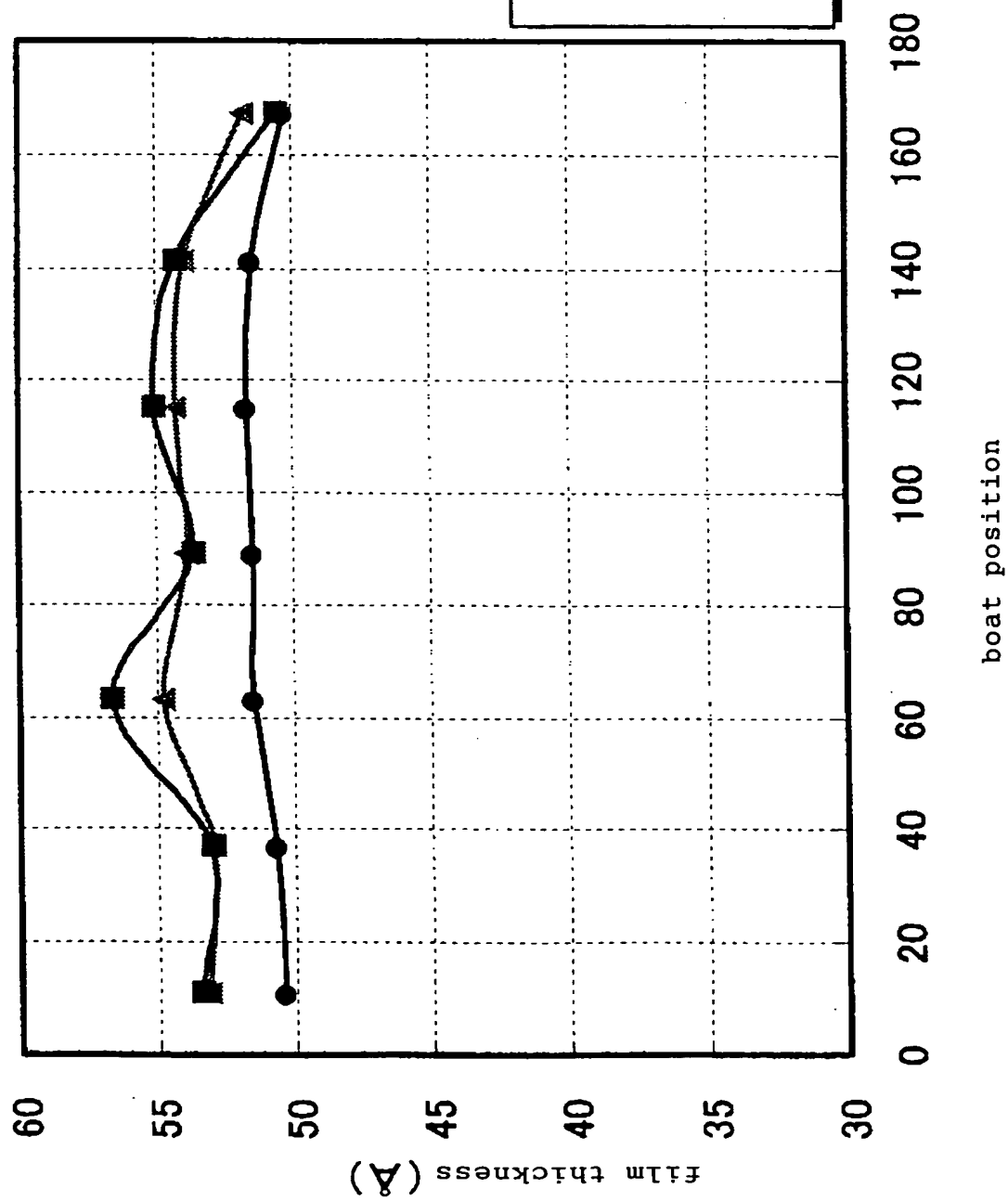
[Fig. 7]



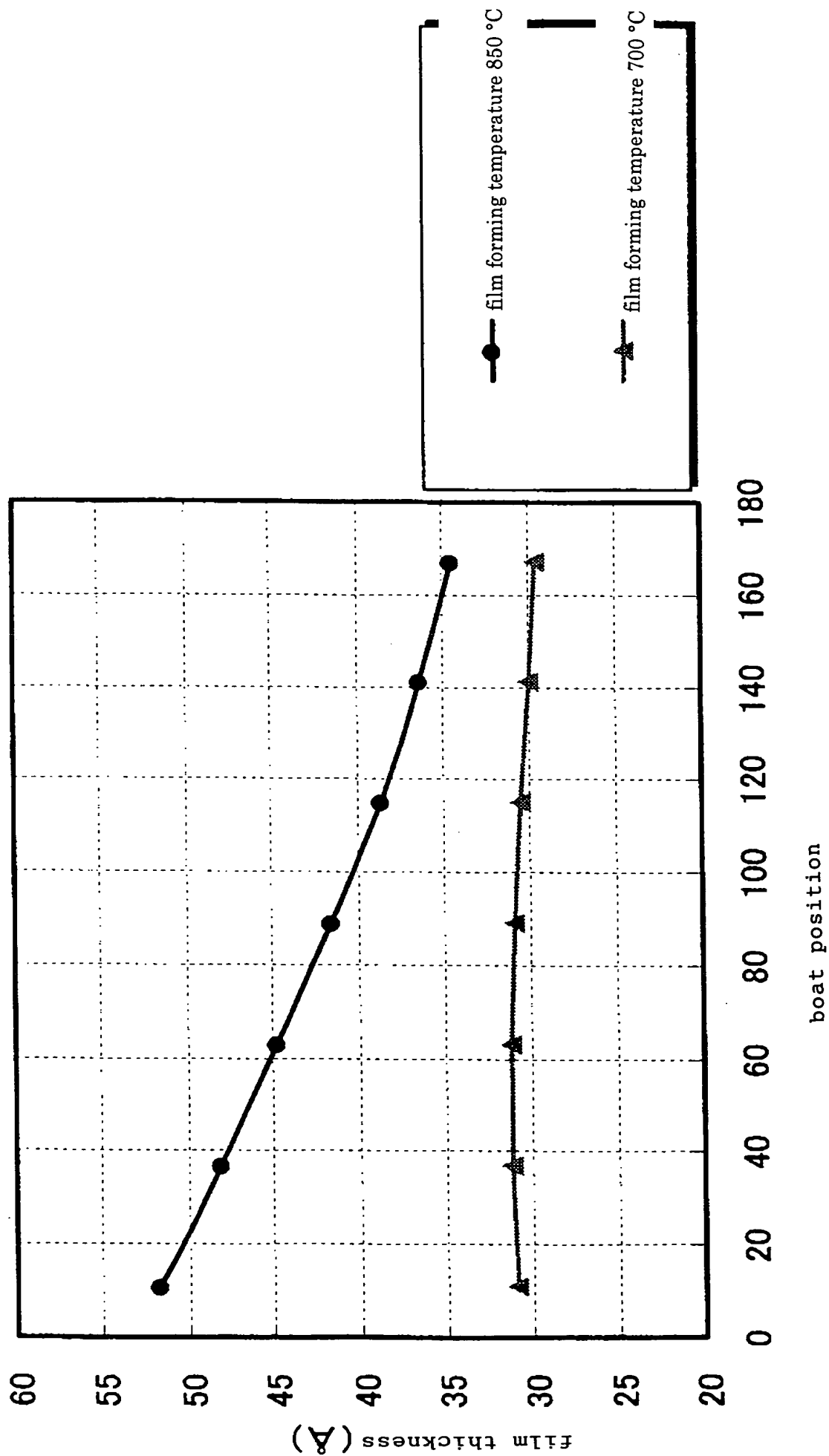
[Fig. 8]



[Fig. 9]



[Fig. 10]



[Document Name] Document of Abstract

[Abstract]

[Object]

It is an object of the present invention to provide a producing method of a semiconductor device and a substrate processing apparatus which are capable of producing a high quality semiconductor device while suppressing a case in which hydrogen concentration is varied depending upon the disposition locations of the substrates and oxide film thicknesses are largely varied when isotropic oxidation is carried out in a batch-type vertical apparatus.

[Means to Solve the Problem]

A producing method of a semiconductor device comprises: a step for transferring a plurality of substrates 1 into a processing chamber 4; a step for supplying oxygen-containing gas from upstream of the plurality of substrates 1 transferred into the processing chamber 4; a step for supplying hydrogen-containing gas from upstream of the plurality of substrates 1 transferred into the processing chamber 4 and from a half-way location corresponding to a region where the plurality of substrates exist; a step for allowing the oxygen-containing gas and the hydrogen-containing gas to react with each other in the processing chamber 4 to oxidize the plurality of substrates 1; and a step for transferring the processed substrates 1 out

from the processing chamber 4, wherein in the step for supplying the hydrogen-containing gas, flow rates of the hydrogen-containing gas supplied from the supply locations are different from each other.

[Selected Figure] Fig. 1